OPENING SIZE AND SITE PREPARATION TECHNIQUES AFFECT REGENERATION SUCCESS FOR UNEVEN-AGED PINE-HARDWOOD MIXTURES[1]

Carol J. Perry and Thomas A. Waldrop[2]

Abstract—Uneven-aged management of pine-hardwood mixtures may provide desirable combinations of timber and nontimber resources if these mixtures can be regenerated in small openings. This study compares pine-hardwood regeneration between several combinations of opening size and site preparation treatments. Treatments included two opening sizes(1/10 acre and 1/3 acre) and three types of site preparation treatments(chainsaw fell noncommercial-sized trees, fell noncommercial trees and apply herbicide, and no treatment). Early results indicate that a balance of hardwood control and available sunlight is required to ensure survival of planted pines. After two growing seasons, most pines were free to grow and had overtopped competing hardwoods. Hardwoods were most vigorous in the larger openings where no herbicide had been applied.

INTRODUCTION

The forest products industry has increasingly come to rely on the resources of the Southeast for fiber production. This is due, in part, to logging restrictions in the Pacific Northwest as well as mandates to establish nontimber objectives for National Forests in all regions. And because Hurricanes Hugo and Andrew destroyed much of the coastal timber resources, management of forested lands in the Piedmont has become extremely important.

Forested lands of hardwood or mixed pine-hardwood stands in the Piedmont Plateau and Appalachian Mountains of the Southeast cover about 26.8 million acres (Bechtold and Ruark 1988). Nonindustrial private forests (NIPF) comprise 72 percent of this acreage. These private forests average about ten acres, are owned by individuals or families, and are typically unmanaged. Many owners choose not to manage because they object to pine monocultures or they do not want to invest heavily in timber (McMinn 1983, Haymond 1988).

Pine-hardwood mixtures are gaining acceptance and new regeneration techniques are proving successful (Waldrop 1994). Productivity of low-quality hardwood stands can be improved economically while maintaining aesthetic values. Uneven-aged pine-hardwood management may prove to be attractive to nonindustrial private landowners as well as national forestlands. However, supporting research is limited.

Extensive research has been conducted using the fell-and-burn technique to regenerate even-aged pine-hardwood mixtures in the Appalachian Mountains (Phillips and Abercrombie 1987) and the Upper Southeastern Piedmont (Waldrop 1994). This project was established to test whether some of the same technology used in the fell-and-burn system could be applied in small openings to establish uneven-aged pine-hardwood mixtures.

Among the questions considered was whether amounts of sunlight, limited by smaller openings, are sufficient for pine establishment. Loblolly pine seedlings are shade tolerant when young, but require more light as they mature (Brender 1973). Another consideration was whether herbicide can successfully replace fire as a site preparation technique. Felling an burning, as described by Phillips and Abercrombie (1987) and Waldrop and others (1989) have proven successful in regenerating mixed pine-hardwood stands, but the use of herbicide to control hardwoods may be more desirable in small openings where the us of fire is not feasible.

Previous research on pine-hardwood regeneration mixtures in clearcuts indicates that loblolly pine

[1]Paper presented at the Eighth Biennial Southern Silvicultural Research Conference, Auburn, AL, Nov. 1-3, 1994.

[2]Forestry Technician and Research Forester, respectively, USDA Forest Service, Southeastern Forest Experiment Station, Clemson, S

seedlings tolerate shade and other forms of competition on medium- to poor-quality sites, and within 5 years overtop surrounding hardwood sprouts (Waldrop and others 1989, Evans 1990). Minckler and others (1973) found that young hardwoods closer to the edge of openings than a distance equal to the height of border trees are suppressed and grow slower than those closer to the center. These findings suggest that mixtures of loblolly pine and upland hardwoods may be regenerated successfully in small openings on medium to poor sites if the edge effect controls hardwood growth enough to allow pines to become established.

This paper documents an attempt to convert an uneven-aged poor-quality Piedmont hardwood stand to an uneven-aged pine-hardwood stand using small openings to create groups. Pine and hardwood regeneration and their relative growth rates through two growing seasons are reported.

METHODS

The study area is in the Upper Piedmont of South Carolina on a 27-acre tract of the Clemson University Experimental Forest in Pickens County. Slopes range from 6 to 10 percent with a uniform southwest exposure. Soils are severely eroded clay loams of the Cecil series. These soils have poor fertility because past land management practices led to erosion of topsoil (USDA Soil Conservation Service 1972). Site index at age 50 years is 70 ft for loblolly pine and approximately 60 ft for upland oaks.

Prior to 1974, the stand was an unmanaged oak-loblolly pine mixture with an average basal area of 100 ft^2/acre (75 percent hardwoods and 25 percent pine). During that year, all pines of commercial size were harvested. In 1989 patches of naturally regenerated loblolly pine occurred throughout the stand in small openings created by that harvest. This regeneration may indicate that loblolly pine seedlings can survive in small openings where indirect sunlight is provided by a southwestern exposure.

This all-aged hardwood stand had a variety of tree ages with some as high as 150 years, and a wide range of dbh classes. White oak (*Quercus alba* L.) was the most abundant overstory species, representing 41 percent of all stems and 30 percent of the basal area (Table 1). Other common overstory species were black oak (*Q. velutina* Lam.) and loblolly pine (P. taeda L.). Common understory species were dogwood (*Cornus florida* L.) and hickory (*Carya* sp.). Basal area was 73 ft^2/acre in 1989.

Prior to treatment installation, the diameters of all trees 2.5 inches dbh and larger were measured. Increment cores were extracted from a sample of 150 trees to examine age distribution. Sample trees were selected over the range of dbh classes and distributed throughout the stand. The relationship of age to dbh was determined with simple linear regression.

In December 1989, six treatment combinations were replicated three times in a randomized complete block design. Treatments included two opening sizes and three levels of hardwood control. Opening sizes of 1/3 and 1/10 acre were chosen because a relationship between opening size and the height of border trees had been reported by Minkler and Woerheide (1965). Circular openings of 1/3 acre have a diameter of approximately two tree heights (136 ft), while 1/10-acre plots (74 ft) have a diameter of approximately one tree height. Levels of hardwood control included: (1) chainsaw felling of residual stems over 6-ft tall; (2) chainsaw felling of residual stems plus application of Garlon™ 3A to all stumps; and (3) no control. Replicates were blocked across the slope (upper, middle, and lower) to remove site differences. Study plots were located away from patches of heavy pine regeneration to minimize variation. Analysis of variance and linear contrasts were used to test for treatment differences at the 0.05 level of confidence.

Trees were harvested on the 1/3 and 1/10-acre treatment plots. All trees over 4.5 inches dbh were felled and limbed on site by research crews. Logs were skidded from the plots by a commercial logger in February 1990. To minimize damage to standing trees, skidder operators used logging roads and skid trails established for the 1974 harvest.

Hardwood control treatments were installed in early March 1990, immediately after logging. All residual stems over 6 ft tall were felled by chainsaw in 12 of the 18 study plots (two opening sizes x three control treatments x three replications). Garlon 3A was applied to all hardwood stumps in half the plots where residuals were felled. The herbicide was applied at full strength with no water. Hardwood control was not attempted in the remaining six openings. Where residuals were not felled, the basal area of residual stems averaged 10.8 ft^2/acre. Genetically-improved loblolly pine seedlings

Table 1–Mean number of stems and basal area per acre before harvest by species group and size class

Species group	Stem dbh class (inches) 2.5-5.4	5.5-9.4	>9.4	Total (percent)
		(stems/ac)		
Oaks				
White	56.3	11.6	14.6	82.5 (41)
Black	9.6	4.5	3.1	17.2 (9)
Scarlet	3.9	2.0	3.3	7.6 (4)
Post	1.8	2.6	4.2	8.7 (5)
Southern red	3.1	1.2	3.3	7.6 (4)
Misc.	0.1	0.1	0.0	0.3 (<1)
Total	74.9	22.1	28.6	125.5 (63)
Other hardwoods				
Yellow-poplar	1.5	0.6	1.2	3.3 (2)
Hickory	9.7	4.8	3.5	18.0 (9)
Dogwood	22.7	1.9	0.3	24.9 (12)
Misc.	10.8	2.3	0.4	13.6 (7)
Total	44.7	9.6	5.4	59.8 (30)
Pines				
Loblolly	2.6	5.9	4.3	12.9 (6)
Shortleaf	1.2	0.0	0.0	1.3 (1)
Virginia	0.1	0.1	0.0	0.3 (<1)
Total	4.0	6.1	4.4	14.4 (7)
All species	123.7	37.8	38.3	199.8(100)
		Basal area (ft^2/ac)		
Oaks				
White	1.3	3.4	17.2	21.9 (30)
Black	0.2	0.8	4.3	5.3 (7)
Scarlet	0.3	0.6	4.7	5.6 (8)
Post	0.2	0.8	4.3	5.3 (7)
Southern red	0.3	0.3	4.7	5.3 (7)
Misc.	0.0	0.0	0.1	0.1 (<1)
Total	3.0	6.4	36.8	46.2 (63)
Other hardwood				
Yellow-poplar	0.1	0.2	2.2	2.5 (3)
Hickory	0.9	1.2	3.6	5.7 (8)
Dogwood	1.8	0.3	0.3	2.4 (3)
Misc.	1.0	4.8	1.6	7.3 (4)
Total	3.8	6.5	7.7	17.9 (25)
Pines				
Loblolly	0.3	1.9	4.1	6.3 (9)
Shortleaf	2.4	0.0	0.0	2.5 (3)
Virginia	0.0	0.0	0.0	0.1 (<1)
Total	2.7	1.9	4.1	8.9 (12)
All species	9.5	14.8	48.7	73.0(100)

were planted by research crews in each opening at a spacing of 12 x 12 feet during the first week of March 1990.

The location of each planted pine was mapped to monitor the relationship of position within a plot to survival and growth. At the end of the first two growing seasons, each pine was tallied as alive or dead and total seedling height and the height at last year's node were measured. Growth was calculated as the difference between the two height measurements. The percentage of each seedling's crown directly covered by nearby vegetation was estimated. Categories included 0, 1-25, 26-50, 51-75, and 76-100 percent covered. Seedlings were considered free to grow if no more than 75 percent of the crown nor the terminal bud were directly covered by competing vegetation. Cover by residual stems over 6 ft tall was not included in estimates of direct cover.

Species composition and growth of hardwood regeneration were measured in September 1990 and 1991. Circular 0.001-acre sample plots were established in a systematic pattern in each opening. Fifty sample plots were created in 1/3-acre openings, while 15 plots were created in 1/10-acre openings. Both samples represent 15 percent of the opening size. All seedlings and sprouts were tallied by species. Height was measured to the nearest 0.1 ft. In sprout clumps, all sprouts were counted and height of the dominant sprout measured.

RESULTS AND DISCUSSION

Prior to harvest, the study stand had large numbers of small trees and small numbers of large trees (Table 1). To avoid high grading, single-tree selection based on diameter requires a close correlation between dbh and age. This did not occur in the study stand (r^2=0.42), where too few stems were in age classes younger than 70 years. Group selection was chosen over single-tree selection to ensure that trees of all dbh and age classes were harvested.

The occurrence of natural pine regeneration was sparse in the stand prior to harvest. Survival of planted pines at the end of the second growing season was fairly high in both opening sizes and with all levels of hardwood control (Table 2). Survival averaged 61 percent in 1/10-acre openings and 65 percent in 1/3-acre openings. However, the number of free to grow pines was significantly less in the 1/3-acre openings (85 percent) than in the 1/10-acre openings (95 percent). The lesser amount of direct sunlight received on the 1/10-acre openings may account for less hardwood and herbaceous growth, thereby reducing competition with planted pines.

Total height of planted pines was not affected by the level of hardwood control within each opening size (Table 2); however, the pines in the 1/3-acre openings were, on average, 9 inches taller than those in the 1/10-acre openings. Second year growth did not differ significantly in any of the treatments except in the 1/3-acre plots where residuals were felled and 1/3-acre plots where residuals were felled and herbicide applied. Pines in these two treatments grew more than those in the remaining four treatments.

Mortality patterns of the planted pines appear to be affected by direct sunlight rather than edge effect.

Table 2–Mean height, growth, and portion free-to-grow for planted pines surviving one growing season

Treatment	Height	Growth	Free-to-Grow
	———feet———		- pct -
1/10-ac openings			
No understory control	2.7a	0.4a	97.1a
Residuals felled	2.2a	0.4a	95.2a
Residuals felled + herbicide	2.6a	0.5a	93.6a
1/3-ac openings			
No understory control	3.2b	0.5a	86.3b
Residuals felled	3.2b	0.6b	88.8b
Residuals felled + herbicide	3.4b	0.6b	80.4b

Means within a column followed by the same letter are not significantly different at the 0.05 level

Table 3–Composition (stems/ac) of hardwood regeneration by treatment

	1/10-ac openings			1/3-ac openings		
Hardwood species	No control	Fell Only	Fell and herbicide	No control	Fell Only	Fell and herbicide
Black oak	600	1479	1378	1061	841	914
White oak	1711	1177	1400	1857	1640	3456
Misc. oaks	578	1422	556	959	512	542
Black cherry	364	534	533	395	858	642
Blackgum	270	711	578	510	968	690
Dogwood	1333	1822	800	1448	4717	1774
Hickory	1222	3978	1755	1244	3317	2069
Yellow-poplar	911	1466	3022	2659	3889	1452
Misc.	289	1600	622	1993	1577	1231
Total	7400	15200	11089	12680	19401	13588

Mortality primarily occurred in the centers and the Northwest corners of the plots in all treatments, where the strongest sunlight was reached the seedlings. The sunlight also promoted a very heavy growth of Rubus sp., which competed intensely with the pines.

Total numbers of hardwood sprouts and seedlings (Table 3) were significantly lower in 1/10-acre openings than in 1/3-acre openings. This may indicate that shading created by edge effect kept hardwood regeneration down. In both opening sizes, the no control plots exhibited less hardwood regeneration than the remaining two treatments, which was expected because the number of stumps was lower. In the remaining plots, less sprouting occurred in the openings receiving the felling and herbicide treatment than those receiving the felling treatment.

Vigor of hardwood regeneration was affected by both opening size and level of understory control. For the oak and other-hardwood categories, the number of sprouts per cut stump was greater in 1/3-acre openings than in 1/10-acre openings (Table 4). Within the 1/3-acre openings, sprouts per stump were most numerous where residuals were felled but no herbicide was applied. In plots where residuals were not felled, sprouts originated from the stumps of commercial-size trees, which were from older trees with reduced sprouting capability. In plots where residual stems were felled and herbicide was applied, the herbicide did not kill the entire stump and root system, but did reduce the number of sprouts produced. This pattern agrees with the results of Lewis and others (1984), who found that

Table 4–Mean number of sprouts per stump by treatment and species group

Treatment	Oaks	Other hardwoods	All hardwoods
1/10-ac openings			
No understory control	1.2a	2.5a	1.9a
Residuals felled	1.7a	2.4a	2.0a
Residuals felled + herbicide	1.8a	1.7a	1.7a
1/3-ac openings			
No understory control	2.2a	2.3a	2.3a
Residuals felled	3.3 b	4.0 b	3.7 b
Residuals felled + herbicide	2.4ab	2.7ab	2.4a

Means within a column followed by the same letter are not significantly different at the 0.05 level.

a winter application of Garlon 3A to the stumps of Piedmont hardwoods killed only a portion of the stumps but effectively controlled sprout growth.

Height of the dominant sprout in each clump was affected by opening size for the other hardwoods and all-hardwood groups (Table 5). Sprouts 1/3-acre openings tended to be taller than those in smaller plots This occurrence is probably a result of reduced competition from border trees. The difference was significant for the other hardwood and all-hardwood species groups. This finding agrees with that of Minckler and Woerheide (1965) who showed that the vigor of hardwood regeneration increased with distance from the edge of the opening. The sprouts exhibiting the most height growth were in the 1/3-acre openings receiving both the fell and fell plus herbicide treatments. The 1/3-acre plots where no residuals were felled exhibited less height growth because residuals standing within the plot increased shade. No significant differences occurred in the oak category.

Table 5—Mean height (ft) of the dominant sprout per clump by treatment and species group

Treatment	Oak	Other hardwoods	All hardwoods
1/10-ac openings			
No understory control	1.7a	2.6a	2.5a
Residuals felled	2.1a	2.3a	2.2a
Residuals felled + herbicide	2.2a	2.4a	2.3a
1/3-ac openings			
No understory control	2.1a	2.7a	2.4a
Residuals felled	2.7a	3.3ab	3.2 b
Residuals felled + herbicide	2.9a	3.7 b	3.3 b

Means within a column followed by the same letter are not significantly different at the 0.05 level.

The relative growth rate of pines and hardwoods is shown in Figure 1. Both pines and hardwoods grew at a faster rate in the 1/3-acre openings than those in the 1/10-acre openings, because amounts of available sunlight were greater. Typically, hardwood growth is represented by a straight line after the first year but pine growth tends to follow a Sigmoid growth curve. In clearcuts, pine growth lags behind that of hardwoods for the first four to five growing seasons (Waldrop 1994). In this study, the planted pines overtopped the hardwoods after only two growing seasons. This may indicate that these particular hardwood species are as sensitive to shading as pines. It appears the hardwoods may be somewhat controlled by the edge effect which promotes more successful pine establishment.

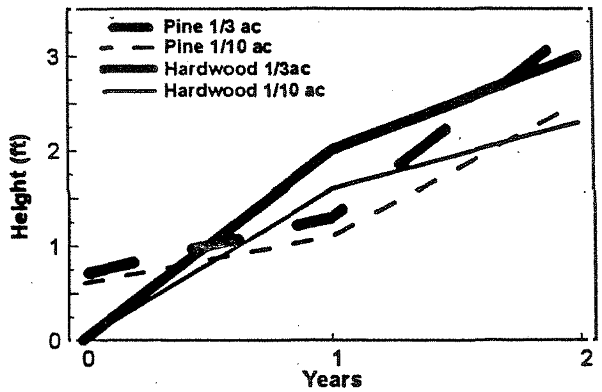

Figure 1—Height growth of pines and hardwoods for two years by opening size

CONCLUSIONS

At the end of two growing seasons, in all of the treatment areas, survival of planted pine and growth of pines and hardwoods was adequate. The smaller 1/10-acre openings allowed some sunlight to reach the ground but the edge effect was substantial. Height growth was somewhat suppressed and applying herbicide did not provide additional benefits. Essentially no differences among the three treatments occurred in the 1/10-acre openings.

The larger 1/3-acre openings allowed more sunlight to reach the ground, and both hardwoods and pines grew better. Numbers of sprouts were very high in the 1/3-acre openings where no herbicide was applied, and herbicidal control of sprouts may prove necessary as the stand continues to develop. In larger opening sizes, a greater amount of control will be necessary for successful pine-hardwood regeneration. However, in both opening sizes, pine heights exceeded hardwood heights; therfore, pine will probably become a major component in this stand.

Little documentation of stand development with uneven-aged mixtures of pines and hardwoods exists. This stand will be monitored for several years to determine the best combination of opening size and level of hardwood control. Continued study of the long-range effects of competition from border trees in uneven-aged stands is needed.

LITERATURE CITED

Bechtold, William A.; Ruark, Gregory A. 1988. Structure of pine stands in the Southeast. Res. Pap. SE-274. Asheville, NC: U.S. Department of Agriculture, Southeastern Forest Experiment Station. 185 pp.

Brender, Ernst V. 1973. Silviculture of loblolly pine in the Georgia Piedmont. Report No. 33. Macon, GA: Georgia Forest Research Council. 74 pp.

Evans, Timothy L. 1990. Effects of fell-and-burn site preparation on wildlife habitat and small mammals in the upper Piedmont of Georgia and South Carolina. Clemson, SC: Clemson University. 52 pp. Masters thesis.

Haymond, Jacqueline L. 1988. NIPF opinion leaders: what do they want? Journal of Forestry 86(4):30-34.

Lewis, J.B.; Zedaker, S.M.; Smith, D. Wm. 1984. Control of stump sprouting in Piedmont hardwoods. pp. 182-191. In: Proceedings, Southern Weed Science Society 37th Annual Meeting Biotechnology and Weed Science. 1984 January 17-19; Hot Springs, AR.

McMinn, James W. 1983. Pine regeneration following fuel chip utilization of mixed hardwood-pine. Georgia Forestry Commission Research Paper 41. 6 pp.

Minckler, Leon S.; Woerheide, John D. 1965. Reproduction of hardwoods 10 years after clearcutting as affected by site and opening size. Journal of Forestry 63:103-107.

Minckler, Leon S.; Woerheide, John D.; Schlesinger, Richard C. 1973. Light, soil moisture, and tree reproduction in hardwood forest openings. Res Paper NC-89. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Fores Experiment Station. 6 pp.

Phillips, Douglas R.; Abercrombie, James A., Jr. 198 Pine-hardwood mixtures: a new concept in regeneration. Southern Journal of Applied Fore 11(4):192-197.

USDA Soil Conservation Service. 1972. Soil Survey Pickens County, South Carolina. Washington, D.C.: U.S. Department of Agriculture, Soil Conservation Service. 70 pp.

Waldrop, Thomas A. 1994. Variations in the fell-and-burn system to regenerate pine-hardwood mixtures in the Piedmont. [These proceedings.].

Waldrop, Thomas A.; Lloyd, F. Thomas; Abercrombi James A., Jr. 1989. Fell and burn to regenerate mixed pine-hardwood stands: an overview of research on stand development. pp. 75-82. In Waldrop, Thomas A., ed. Proceedings of pine-hardwood mixtures: a symposium on managem and ecology of the type; 1989 April 18-19; Atlan GA: Gen. Tech. Rep. SE-58. Asheville, NC: U.S Department of Agriculture, Forest Service, Southeastern Forest Experiment Station.

Proceedings of the Eighth Biennial Southern Silvicultural Research Conference

Compiled by

M. Boyd Edwards

Auburn, Alabama
November 1-3, 1994

Sponsored by

Southern Forest Experiment Station

Southeastern Forest Experiment Station

Southern Region of the National Association of Professional Forestry Schools and Colleges

Southern Industrial Forestry Research Council

Silvicultural Working Group of the Society of American Foresters

Hardwood Research Council

Southern Group of State Foresters

National Association of Consulting Foresters of America

Historically Black Colleges and Universities Program

Published by

USDA Forest Service
Southern Research Station
Asheville, North Carolina
December 1995

Edwards, M. Boyd, comp. 1995. Proceedings of the eighth biennial southern silvicultural research conference; 1994 November 1-3; Auburn, AL. Gen. Tech. Rep. SRS-1. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station. 633 p.

Eighty-eight papers and two abstracts address a range of issues affecting southern forests. Papers are grouped in several categories including a general session, ecosystem management, vegetation management, pest management, natural disturbance, biometrics, economics, site productivity, site impacts, ecophysiology, genetics, regeneration, silvicultural systems, stand development, and intermediate management. Fourteen papers, on varying topics, are presented from a poster session.